AN ASSESSMENT OF ENGINEERING NOISE CONTROLS AT A TALC PROCESSING PLANT

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Abstract

National Institute for Occupational Safety and Health (NIOSH) researchers conducted an investigation to quantify sound levels and to determine the amount of sound reduction provided by engineering noise controls installed in a talc processing plant. Baseline sound level and sound intensity measurements were performed at the plant and the measurement locations were recorded for comparison to post-control measurements. Follow-up measurements were then made at the same locations after the initial noise controls were installed. The plant subsequently decided to implement additional noise controls and the researchers returned to conduct measurements for a final analysis of all noise controls. The most significant results showed a sound level reduction in the main mill area from a range of 93-104 dB(A) down to 90-94 dB(A), and a total sound power level reduction of 21 dB(A) for air classifying mill 3.

Introduction

In 2003, over 12,000 nonmetal employees worked in preparation or mill plants (1). A NIOSH study revealed that by age 50, approximately 49% of metal/nonmetal miners have a material hearing impairment (2). Accordingly, there is potential for almost 6,000 nonmetal processing plant workers to be hearing impaired by age 50. This study's noise control work will be useful for the approximately 150 nationwide nonmetal processing plants (3) to help them reduce the sound levels of their mills.

With the cooperation of mine officials at a talc processing plant, NIOSH conducted a study to quantify in-plant sound levels and to determine the amount of sound reduction provided by engineering noise controls installed by mine personnel. The long-term goals of the mine officials were to reduce in-plant sound levels and worker noise exposure. The noise control evaluation at the talc processing plant was performed as part of NIOSH's effort to locate and evaluate state-of-the-art engineering noise controls. In addition to locating and assessing existing controls, NIOSH is also identifying processes or machines in need of noise controls, gaps in technology that impede the use of noise controls, and barriers to the use of noise controls, including collateral hazards (4). The specific noise controls for this study – acoustic curtains, and sound barrier and sound absorber materials – as well as the theoretical concepts can be applied to not only talc plants but to other comparable machinery in all industrial sectors. The noise control retrofit treatments for mining machinery can be found in the Bureau of Mines handbook, "Mining Machinery Noise Control Guidelines"(5). There is a high level of consensus about the theory, appropriate principles, and evaluation methods for engineering noise controls (6,7,8,9). This study applied the consensus noise control approach by identifying and quantifying noise sources, developing appropriate engineering and administrative controls, and quantifying the extent of noise reduction attributable to each control intervention alone and in combination.

To identify noise sources and their relative importance, baseline sound level and sound intensity measurements were performed with equipment turned on or off in a pre-selected process. The sound levels and their measurement locations were then entered into SSG-Surfer™ software[1] to produce sound level contour mappings of the mill floor area. Temporary and fixed acoustic curtains and sound absorption material were then used, and post-control sound level and sound intensity measurements were taken to further identify the noise sources. After additional engineering noise controls were installed, sound level and sound intensity measurements were taken to quantify the post-control noise levels and the effectiveness of the control(s). For this study, the sound level measurement was averaged for at least 12 seconds (time determined by researcher using B&K and American National Standards Institute (ANSI) recommendations), at each location (10). Figure 1 is a top view of the main mill area showing each numbered measurement location. During these measurements, the Bruel & Kjaer[1] (B&K) 2260 Investigator™ was mounted on a tripod such that the measurement microphone was 1.43 meters (56 inches) above the floor (11).

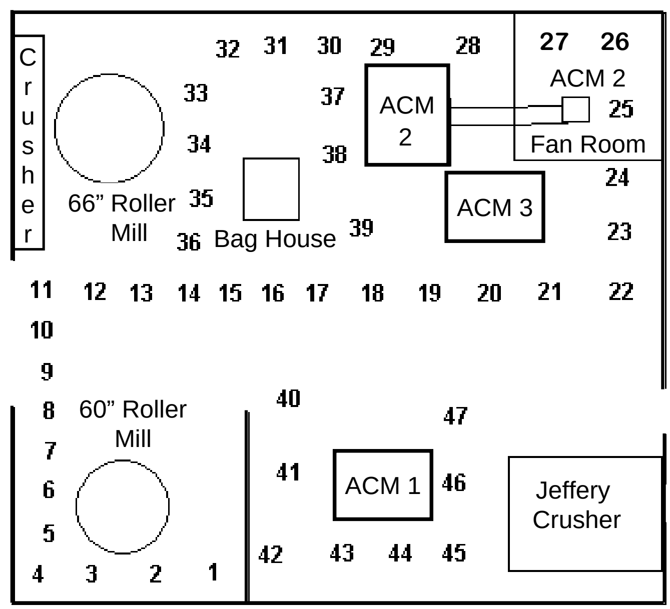

Figure 1. Sound level measurement locations (not to scale).

The work patterns and employee locations in this facility fluctuated unpredictably depending on events that occurred during talc processing. In most cases, employees would be moving in and out of the noisiest areas, and their exposures would probably be very low. However, the mine officials felt that unusual situations could arise where workers would spend prolonged periods of time in the noisy areas. These situations were too unpredictable to be captured reliably through standard full-shift dosimetry. Instead, the scope of the current study was limited to reducing noise sources with the expectation that dose reductions could be verified later, if necessary.

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[1]Reference to specific brand names does not imply endorsement by the National Institute for Occupational Safety and Health.

Sound Level Measurements

Sound level measurements were conducted at 47 locations, approximately 2 meters (79 inches) apart, on the processing plant floor under full operating conditions without and with noise controls installed. A spot marking each measurement location was painted on the concrete floor to make the repeated measurements as consistent as possible. At every measurement location, the A-weighted equivalent continuous sound pressure level (L_{Aeq}) spectrum was measured using a B&K 2260 Investigator™ running Enhanced Sound Analysis software. The reference used when dealing with sound pressure is 2 x 10^{-5} Pascals (Pa), which is the sound pressure that is barely audible at 1,000 Hz. When measured, this sound pressure would yield a value of 0 dB. The term "level" is commonly used to designate a logarithmic ratio of relevant parameters. Therefore, a sound pressure equal to the reference pressure of 2 x 10^{-5} Pa (1 Pascal = 1.45 x 10^{-4} pound per square inch) produces a sound pressure level (SPL) of 0 dB. In order to quantify the change in pressure at any point due to a passing sound wave, the root-mean-square (RMS) value is used. The SPL for any sound can be calculated using the equation:

$$\mathrm{SPL} = 20\log \times \left(\frac{P_{RMS}}{P_{ref}} \right) \qquad (1)$$

where:

P_{RMS} = root mean square sound pressure in Pascals; and
P_{ref} = reference sound pressure, 0.00002 Pascals (12).

Sound Intensity Measurements

Sound intensity measurements were made to locate primary noise sources and then repeated to quantify the effectiveness of the noise control efforts. Sound intensity is a vector quantity that describes the rate of energy flow through a unit area. As detailed in Figure 2 (13), as noise radiates out from a hypothetical point noise source, the sound power *P* passes through an area at a distance *r* from the point source (14). The equation to calculate the intensity (I) passing through this area is:

$$I = \frac{P}{4\pi r^2} \qquad (2)$$

where: $4 \pi r^2$ = area of the surface of the sphere.

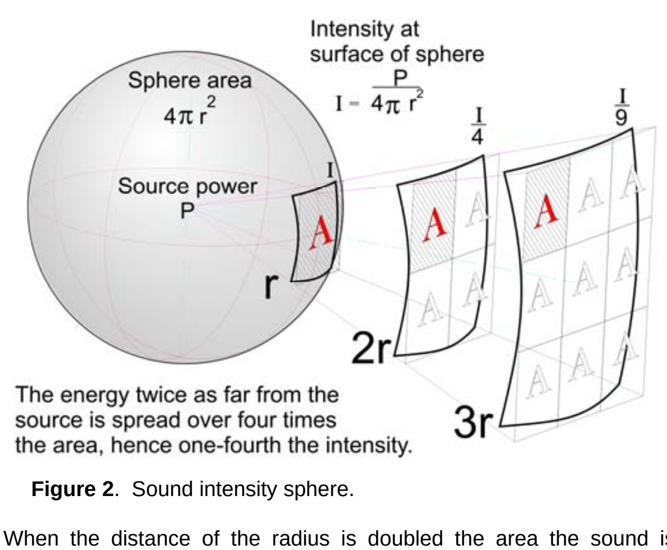

Figure 2. Sound intensity sphere.

When the distance of the radius is doubled the area the sound is passing through is four times as large but the power stays the same, resulting in the new equation:

$$I = \frac{P}{16\pi r^2} \qquad (3)$$

Using the baseline sound level contour plot, the machine, or an area of the machine, most responsible for high sound levels was identified for a sound intensity analysis. The B&K 2260 Investigator™ running Sound Intensity software was used for the sound intensity measurements. For this study, the discrete point sound intensity measurement technique was used. To use this technique, measurements are made on a grid covering the measurement surface with the intensity probe normal and parallel to the measurement surface at a constant distance. The grid dimensions vary depending on the size of the measurement area and the desired degree of frequency and spatial resolution. The measurement grid is necessary since the sound intensity measurements are repeated at least twice for every test condition. In this study, the researcher used a permanent marker and delineated the row-and-column grid area onto the machine surface. Then a 15-second sound intensity measurement (time determined by the researcher using B&K and ANSI recommendations) was taken 0.1 meters (4 inches) from the surface at each grid point using the Investigator with the intensity probe (15). The sound power level of the grid area is calculated by the Investigator using the sound intensity measurements and grid dimensions, as shown in equation 3 (15). Comparison of the sound power calculations with and without the noise control in place can be used to directly measure the performance of the control.

Results and Discussion

Figure 3 (see Appendix B) shows four different operating conditions during the noise control study. Sound level measurements were taken in the mill during; a) Baseline (no noise controls installed), b) initial acoustic curtains, c) additional acoustic curtains in front of the ACMs, and d) fully installed noise controls testing. The controls in each operating condition are explained below.

Sound Level Measurements - Baseline

To identify noise sources it is recommended to turn components on and off while taking measurements (9). For the initial visit to the processing plant sound levels were measured under different operating conditions (e.g., fluid energy mill (FEM) fans, roller mills or crushers off and/or an air classifying mill (ACM) off – Table 1, see Appendix A). These measurements were used to further identify the noise sources by taking baseline measurements with certain machines turned on and/or off and then using acoustic curtains and sound absorptive material around or next to certain machines, repeating the measurements, and comparing the results. The baseline sound levels with all machines operating ranged from 93 dB(A) to 104 dB(A) with the highest levels being measured near ACM 3. The long-term goals expressed by the plant's management were to reduce in-plant sound levels and noise exposures of employees. Measuring the baseline sound levels with all equipment operating and measuring the resulting reduction of sound levels after the noise controls are implemented will quantify these goals for the company and demonstrate potential noise reduction.

Sound Level Measurements – initial engineering noise controls

For the initial engineering noise controls, and to quantify the contribution to the sound level from these machines, temporary noise controls were recommended to isolate and identify noise sources (9). For the study acoustic curtains were installed around the FEM fans (Figure 4) and the Jeffrey crusher (Figure 5). Both of these controls were located on a level above but open to the main mill floor. The ACM 2 fan room is also above the floor area, but fully enclosed and not a significant noise contributor. Additional curtains were added to block sound radiating from the lower part of the Jeffrey crusher on the first floor. With the FEM fans and crushers operating, a sound level reduction was achieved in the main mill area from a baseline range of 84-91 dB(A) down to an initial control range of 83-89 dB(A) – Table 1. While this reduction of about 2 dB(A) is a small numeric change, a reduction of 3 dB(A) would be attributed to reducing the sound energy of the noise source by half (16). Further, when taken in context with the additional controls to be implemented, this initial step was significant because it reduced these noise sources' sound energy by almost 35%, identified the sound level contributions of these noise sources, and allowed a progression to the next noise control effort.

Figure 4. Curtains around FEM fans.

Figure 5. Curtains around Jeffery crusher.

To study the noise contribution of the ACMs to the main mill area, temporary welding screens draped with acoustical curtains were placed in front of the ACMs. The installation of one of these barriers, in front of ACM 2, is shown in Figure 6. Also, because of the high sound levels measured next to ACM 2, sound absorbing material was inserted under the hood of ACM 2. Under the same operating conditions, the sound levels without noise controls ranged from 90-98 dB(A), while the sound levels with noise controls ranged from 88-94 dB(A) (Table 1, Operating Condition 6). The curtains reduced the sound levels around ACM 1 and ACM 3 by about 2 dB(A), additionally, while using the sound absorbing material under its hood with the curtains around ACM 2 reduced the sound level in front of ACM 2 from 96 to 92 dB(A). This reduction of 4 dB(A) would be attributed to reducing the sound energy contribution of the noise source to the main mill area by over 40% (16).

Figure 6. Acoustic curtain being placed in front of ACM 2.

To further identify the source of the high sound level of 104 dB(A) measured at Location #20 in Figure 1, sound intensity measurements were taken in front of ACM 3, designated as Surface 1. Figure 7 shows the measurement grid and the initial sound intensity contour map overlaid on a picture of Surface 1. It can be seen in Figure 7 that the highest intensity level of 109 dB(A) was measured around the center of the ACM. The calculated sound power level of the grid area is 104 dB(A) – Figure 8. A frequency analysis of ACM 3 showed a high level at 800 Hz. This calculated high sound power level was due mainly to this peak and most likely corresponded to the fan blade pass frequency. Once these results were discussed with plant management, the ACM 3's fan was balanced and the shroud door sealed. Sound intensity measurements after these maintenance and repairs were done ranged from 85 dB(A) to 96 dB(A). The reduction of the calculated sound power was 12 dB(A).

Sound Intensity Measurements - air classification mill 3

Since a significant sound level reduction of about 3 dB(A), from an average of 95 dB(A) down to about 92 dB(A), was achieved using the acoustical curtains in front of the ACMs, it was decided to engineer noise controls for ACM 3. A larger shroud for ACM 3 was built and the interior of the shroud was lined with commercially available sound barrier and sound absorber materials - Acoustiblok®[1] and Bafl-sorp®[1], respectively. The sound intensity measured after the new acoustical shroud was in place ranged from 76 dB(A) to 86 dB(A), the reduction of the calculated sound power level was 9 dB(A), and the sound level was reduced by about 7 dB(A) in this area of the plant. Taken alone, this total reduction would be attributed to reducing the sound power contribution of Surface 1 by over 90% (16).

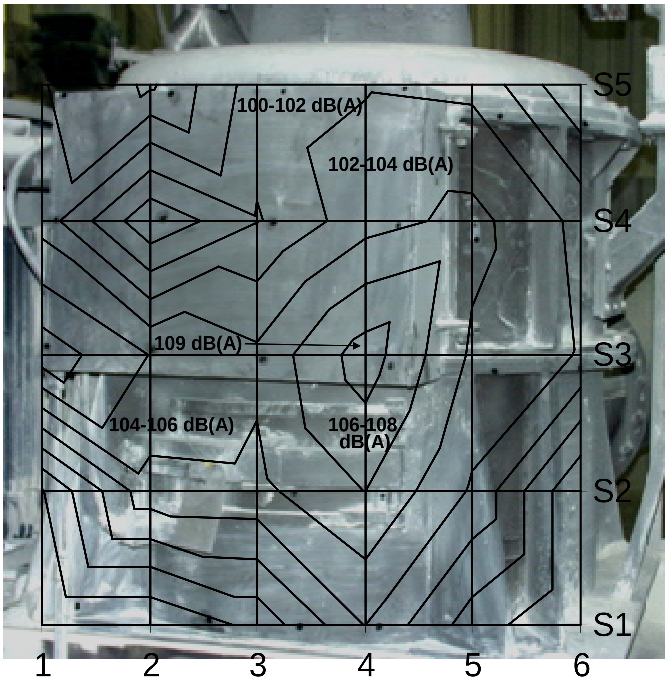

Figure 7. Sound intensity measurement grid on Surface 1 of ACM 3.

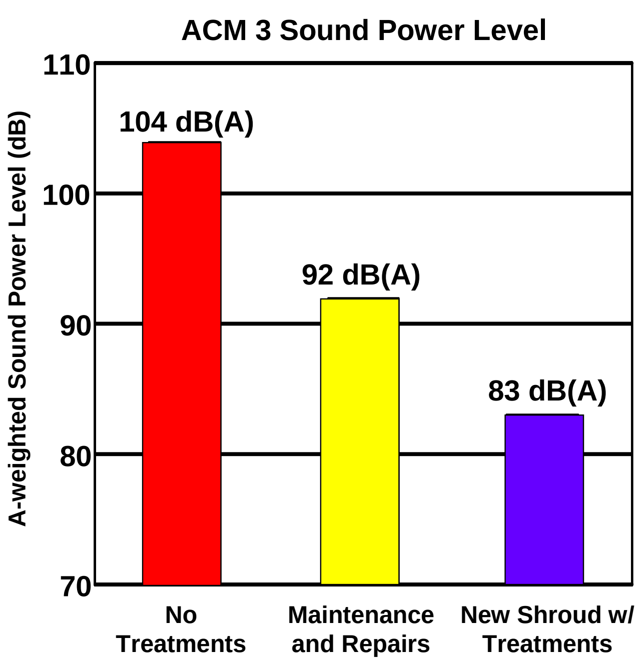

Figure 8. Calculated sound power for no noise control treatments, maintenance and repairs, and noise controls on Surface 1 of ACM 3.

Sound Intensity Measurements - air classification mill 3

Since a significant sound level reduction of about 3 dB(A), from an average of 95 dB(A) down to about 92 dB(A), was achieved using the acoustical curtains in front of the ACMs, it was decided to engineer noise controls for ACM 3. A larger shroud for ACM 3 was built and the interior of the shroud was lined with commercially available sound barrier and sound absorber materials - Acoustiblok®[1] and Bafl-sorp®[1], respectively. The sound intensity measured after the new acoustical shroud was in place ranged from 76 dB(A) to 86 dB(A), the reduction of the calculated sound power level was 9 dB(A), and the sound level was reduced by about 7 dB(A) in this area of the plant. Taken alone, this total reduction would be attributed to reducing the sound power contribution of Surface 1 by over 90% (16).

Sound Intensity Measurements - 60" roller mill duct

The area near the duct work of the 60" roller mill (Figure 9) was identified by an analysis of the baseline sound level measurements as a noisy area – Figure 3(a), ≥ 94 dB(A). The baseline sound intensity measurements on the duct, shown as a sound intensity contour plot in Figure 10, ranged from 82 dB(A) to 98 dB(A). The calculated sound power level was 93 dB(A). Using a recommended noise control technique (9) the duct was wrapped with a sound barrier material. Figure 11 shows the duct after the treatment was applied. The sound intensity measurements on the treated duct ranged from 82 dB(A) to 93 dB(A) as shown in Figure 12. The calculated sound power level for the measurement surface was 90 dB(A). The reduction of the sound power level was 3 dB(A), contributing to the overall a sound level reduction of about 2 dB(A) in this area of the mill. It can be seen in Figure 9 that the highest sound intensity levels were measured in the middle of the duct. The treatment reduced the sound intensity in this area by over 10 dB(A). The reduction of the sound power level by 3 dB(A) would be attributed to reducing the sound energy of the noise source by 50% (16).

Figure 9. Untreated roller mill duct.

Sound Level Measurements – all engineering noise controls installed

The installed engineering noise controls consisted of: a) acoustic curtains around the FEM fans and the crushers, b) acoustic curtains in front of ACM 1 and 2 and absorptive noise control material inserted under the hood of ACM 2 c) a larger shroud for ACM 3, filled with a noise barrier and noise absorptive material and d) 60" roller mill duct wrapped with noise barrier material. It must be noted that simple maintenance and repairs on ACM 3 reduced the sound level directly in front of ACM 3 by about 10 dB(A). Therefore, a second baseline was established (Table 1, Operating Condition 7). This was before the follow-up test measurements with initial noise controls installed were taken. For the final test, the main mill area sound levels were again measured using the same 47 measurement points that were used during the initial visit. The second baseline sound level measurements ranged from 91 dB(A) to 100 dB(A). After the implementation of controls the sound levels ranged from 90 dB(A) to 94 dB(A) – Table 1.

A long-term goal of the mine officials to reduce in-plant sound levels was accomplished and this will subsequently reduce worker noise exposure. The remaining levels are still hazardous, so administrative controls and hearing protection devices (HPDs) are still needed to avoid the risk of hearing damage. It is more likely that HPDs will provide adequate protection for noise levels of 90-94 dB(A) than the pre-controls levels exceeding 100 dB(A). Before the controls worker over-exposure to noise would occur in the loudest area of the mill in about one hour, now over-exposure would occur in about 5 hours, under MSHA criteria (17).

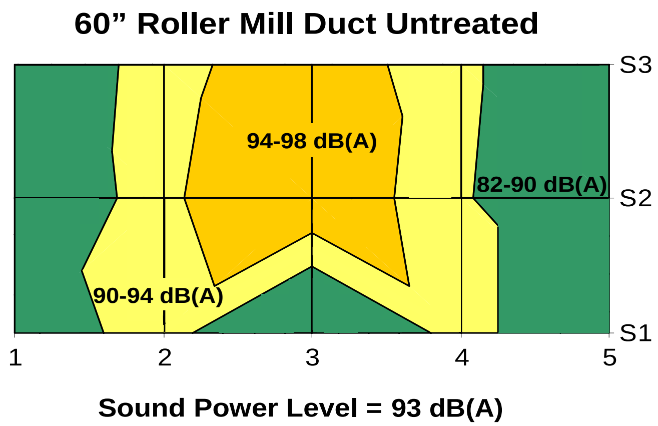

Figure 10. Sound intensity measurement results on untreated 60” roller mill duct.

Figure 11. Duct work treated with a sound barrier material.

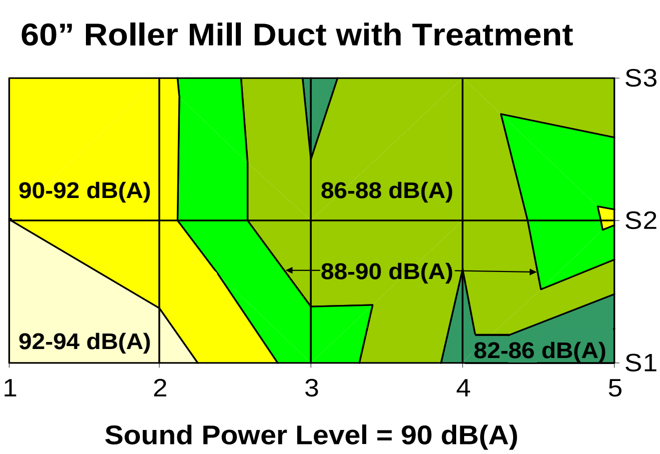

Figure 12. Sound intensity measurement results on treated 60” roller mill duct.

Disclaimer

The findings and conclusions in this report have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Summary

With the cooperation of mine officials, the National Institute for Occupational Safety and Health (NIOSH) conducted a study to quantify sound levels and to determine sound reduction provided by engineering noise controls installed in a talc processing plant. Sound intensity and sound level measurements were performed in the plant before and after installing noise controls.

The baseline sound level measurements ranged from 93 dB(A) to 104 dB(A). The initial engineering noise controls consisted of acoustic curtains installed around the FEM fans and the Jeffery crusher. Acoustic curtains were then used in front of the other crusher and the ACMs, sound absorbing material was inserted under the hood of ACM 2, and maintenance and repairs on ACM 3 were completed. The sound levels measured after this work was completed ranged from 88 dB(A) to 94 dB(A), a significant reduction of 10 dB(A) from the highest baseline sound level. For the loudest ACM, the noise controls consisted of building a larger shroud, lining the inside of the shroud with a sound barrier material, and filling the interior of the shroud with sound absorbing material. Sound intensity measured after the new shroud was in place ranged from 76 dB(A) to 86 dB(A), and a remarkable reduction in the sound power level of 9 dB(A) was achieved on the measurement surface. The final control for this study was wrapping the duct of a 60” roller mill with a sound barrier material. The highest sound intensity measurement of the duct was reduced by 6 dB(A) and the sound power level on the measurement surface was reduced by 3 dB(A). The main mill area second baseline sound level measurements taken after maintenance and repairs on ACM 3, ranged from 91 dB(A) to 100 dB(A). The final noise control sound levels measurements were reduced to a range of 90 dB(A) to 94 dB(A). Using these or similar controls at the other U.S. nonmetal processing plants could reduce the exposure of roughly 6,000 workers. Mine management would still have to use administrative controls or require the workers to wear hearing protection to reduce the risk of hearing damage, but the extent of over-exposure was decreased significantly. MSHA’s preferred method for assessment of miners’ exposure and noise controls involve full shift dosimetry along with time-motion studies. While this method was not accomplished here, an assessment of the sound level reduction increases the time a worker can spend in the mill without being overexposed to noise by about 4 hours. The significant noise reductions that were obtained through noise controls and repairs would necessarily reduce exposure, especially in the unusual situation where workers needed to remain in the noisiest areas for prolonged periods. Capturing these atypical situations through full-shift dosimetry was beyond the scope of the current study.

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Appendix A

Table 1. Sound level measurements in the main mill area.

Operating Condition	Baseline Sound Level Measurements Range dB(A)	Second Baseline[1] Sound Level Measurements Range dB(A)	Initial Controls[2] Sound Level Measurements Range dB(A)	Final Test[3] Sound Level Measurements Range dB(A)
1) FEM fans – On	79-89	78-89	78-88	
2) FEM fans and crushers – On	84-91	86-91	83-89	79 [(a)]-92
3) FEM fans, crushers, and ACM 2 – On	87-92			
4) FEM fans, crushers, and ACM 3 – On	87-104			
5) FEM fans, crushers, all ACMs, and 60" roller mill – On	92-106	91-98		
6) FEM fans, crushers, all ACMs, and 66" roller mill – On		90-98	88-94 [(a)]	
7) FEM fans, crushers, all ACMs, 60" and 66" roller mills – On	93-104	91-100	90-99	90-94 [(b)]
8) All Machines – Off (background measurements)		70-81		

[1]Sound level measurements were taken after maintenance and repairs to ACM 3, with no controls installed.

[2]Initial noise controls; acoustic curtains around FEM fans and Jeffrey crusher, and maintenance and repairs on ACM 3, operating conditions 1, 2, and 7 were measured.

a. For the measurement of operating condition 6, additional temporary welding screens draped with acoustical curtains were placed in front of the ACMs and absorptive noise control material was inserted under the hood of the ACM 2.

[3]Engineering noise controls installed.

a. The low range is suspect because material stopped flowing through the Jeffery crusher while measurements were being taken in that area.

b. One FEM was not operational, but was not considered to be a major noise source contributor per Baseline and Second Operating Condition 1.

Appendix B

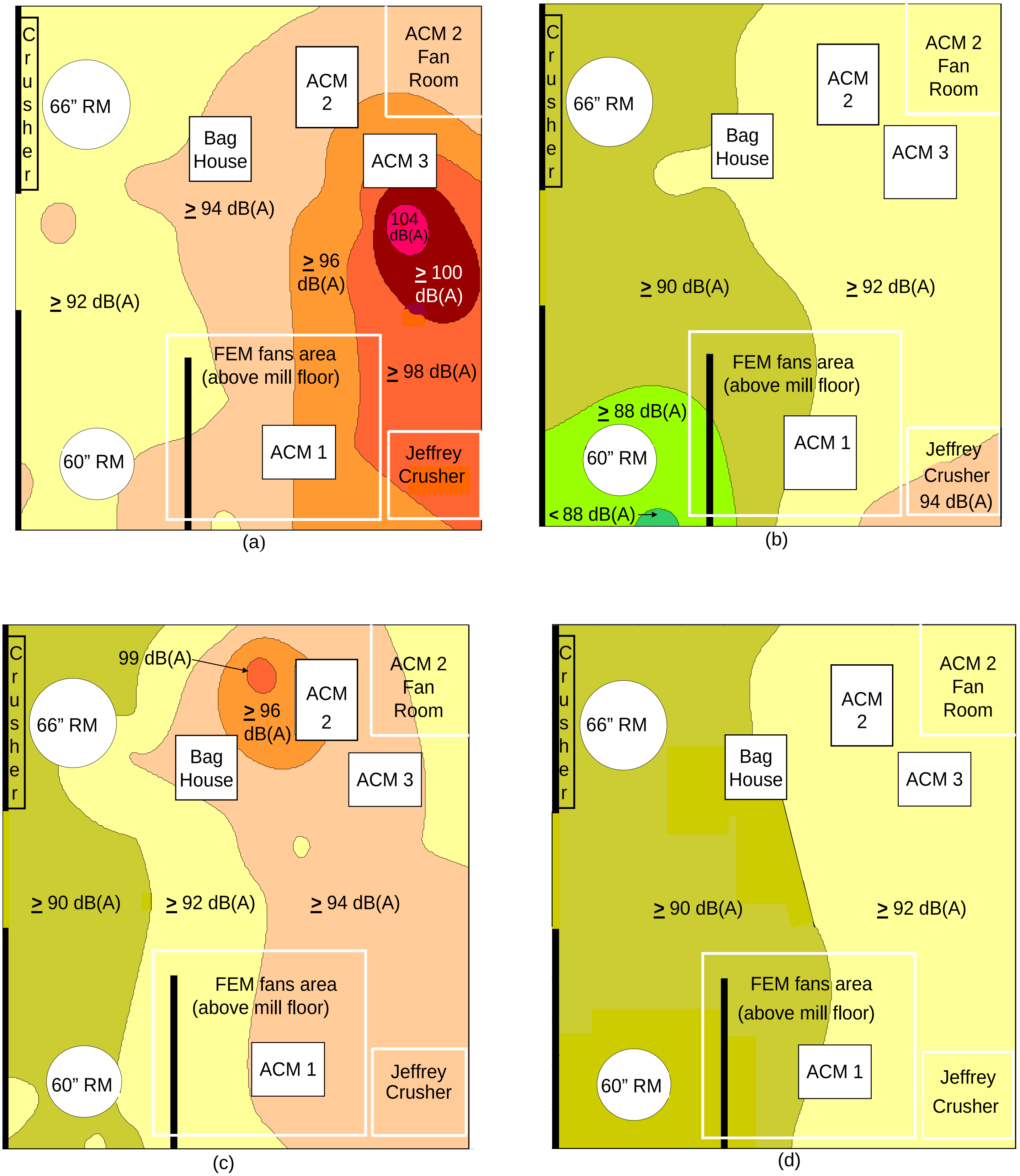

Figure 3. Contour maps for **(**a) Baseline (b) acoustic curtains around the FEM fans and upper and lower levels of the Jeffrey crusher (c) acoustic curtains around the FEM fans, upper and lower levels of the Jeffrey crusher, and in front of ACMs (d) all engineering controls